CAPE WIND ASSOCIATES LLC

115 kV Solid Dielectric Submarine Cable

Section 6 – Technical Specifications

Revision 1
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1. SYSTEM DESCRIPTION

1.1 Proposal general description

This section details the cable and system design proposal relevant to the 115 kV submarine composite power/optical cables and their relevant accessories, necessary for the interconnection between offshore ESP (Electrical Service Platform) and the 115 kV upland cables through transition joints in the vaults at landfall.
The nominal route length of the submarine section is about 12.2 miles (about 19.63 km).
The submarine cables will be buried along the entire route length at about six (6) feet depth.
At the shore end approach the cables will be individuially protected by means of URADUCT protective shells and will enter the vaults via HDPE pipes.
At the splice chamber will also carried out the splicing between the submarine and the upland fibre optic cables.
The cable design is based on the operating parameters and the electrical, environmental and installation conditions stated in item 1.3 of this document.

1.2 Selection of cable type

The requirement of carrying 454 MW is achieved by sharing the total power rating into four (4) three-core cables, carrying 113.5 MW/each.
The above four cables will be installed as two separate circuits by bundling two cables together per circuit during installation and installing the two circuits with a minimum of 20 feet spacing apart along the route.
This provision will allow limiting to two the number of submarine trenches to be excavated.

For this offer we are proposing a three-core, sized 800 mm^2, XLPE insulated, lead/PE sheathed and single wire armored composite submarine cable, incorporating n° 1 fiber optic interstitial unit equipped with 24 single mode ITU-T G.652 fibers. Cable construction is in accordance with IEC standards criteria and Manufacturer's rules.

The results obtained from a marine survey campaign have shown a substantial reduction in the thermal resistivity and an increase in the ambient temperature values compared to those considered in our first proposal (0.5 Kxm/W and 19 °C instead of previous 0.8 Kxm/W and 17 °C).
This has allowed using the same cable as already proposed in our previous offer.
Nevertheless, the increase in the total power rating from 1160 A to 1262 A is such that at the shore end approach it is necessary to consider a cable spacing wider than the one considered on the drawing supplied from Cape Wind LLC in order to allow the above rating.
Our proposal is stated in item 1.3.

1.3 Electrical, environmental and installation data

Here below, all parameters given or assumed (A) for calculating cable system current ratings are mentioned.

1.3.1 Electrical

Rated r.m.s. AC nominal voltage between phases (U)	kV	115
Rated r.m.s. AC nominal voltage phase to ground (Uo)	kV	66.4
Highest continuous r.m.s. phase to phase voltage (Um)	kV	123
Lightning Impulse Withstand peak (Up)	kV	550
Rated frequency	Hz	60
Total output maximum rated power	MW	454
Total output maximum rated current	A	2525 [1]
Daily load factor	%	100 [2]
Fault current/duration (both single-phase and three-phase)	kA/cycles	40/38.5

1.3.2 Environmental

Maximum temperature of seabed (at 6 ft depth)	°C	19 [3]
Maximum seabed thermal resistivity	K×m/W	0.5 [3]

1.3.3 Installation

1.3.3.1 Open sea

Cable directly buried in the seabed		
Nominal burial depth (on top of the cables)	ft	6
Number of circuits		2
Number of cables per circuit		2
Axial spacing between cables in the same circuit	ft	touching
Minimum axial spacing between circuits	ft	20

1.3.3.2 Shore approach

<u>URADUCT portion</u>

Cable directly buried in the seabed with URADUCT protection		
Estimated URADUCT thickness	mm	35

[1] Based on 0.95 power factor and a receiving voltage at Nstar's Barnstable Swithching Station of 109.25 kV
[2] For design purposes.
[3] From marine survey results.

Nominal burial depth (on top of the cables)	ft	6
Number of circuits		2
Number of cables per circuit		2
Minimum axial spacing between cables in the same circuit	ft	7
Minimum axial spacing between adjacent cables of the two circuits	ft	14

<u>HDPE pipe portion</u>

Cable directly buried in HDPE pipes, filled with bentonite compound

Nominal burial depth (on top of the pipes)	ft	6
Number of circuits		2
Number of cables per circuit		2
Axial spacing between pipes in the same circuit	ft	2 [4]
Axial spacing between adjacent pipes of the circuits	ft	5.7 [4]

Note: from a thermal viewpoint, the URADUCT portion represents the most critical portion of the entire submarine link. Therefore, the minimum cable spacing needed to guarantee the maximum cable rating shall be checked as a function of the effective URADUCT thickness and burial depth.

1.4 Thermal design

The thermal design has been carried out considering the worst thermal conditions and assuming the following maximum conductor temperatures:

- 90 °C for normal operating condition
- 105 °C for emergency condition
- 250 °C for short circuit condition

Thermal calculations have been performed for the Nominal Load Condition and for Emergency.
The calculation method is shown in the IEC recommendation 60287 "Calculation of the Continuous Current Rating of Cables (100% load factor)", integrated with the IEC recommendation 60853 “Calculation of the cyclic and emergency current rating of cables. Part 2: Cycling rating of cables greater than 18/30 (36) kV and emergency ratings for cables of all voltages”.
The short circuit calculations have been carried out according to IEC recommendation 949 “Calculation of thermally permissible short-circuit currents, taking into account non-adiabatic heating effects”.
The assumptions taken for thermal design calculations are those mentioned in item 1.3 of this document.

The allowable submarine cable overload is indicated in item 5, Figure 1.

[4] At vault entrance.

1.5 Electrical design

The nominal insulation thickness is set to 15 mm, which gives rise to nominal voltage stresses, measured at the conductor screen and at the insulation screen surfaces, as follows:

Voltage Stress (kV/mm)

at conductor screen	*at insulation screen*
6.05	3.35

1.6 Mechanical design

The mechanical design of the submarine cables consist in the verification of the mechanical stresses to which each layer is subjected.
All main cable components have been calculated in such a manner as to give rise to acceptable stresses during manufacturing, loading, transport, laying, service and recovery.
As far as the intrinsic cable mechanical protection is concerned, we have provided a wire armoring protection in the form of a single layer of 6 mm diameter galvanized steel wires.
In our opinion, this type of protection is suitable to ensure that the cable is able to withstand the rigors of installation (tension, crushing and abrasion), and to guarantee the cable integrity against the mechanical stresses deriving from the manufacturing handling.
As required, the cable will be protected along the entire route length by direct burying at the specified burial depths.

1.7 Grounding

All the submarine cables metallic protections shall be solidly bonded and grounded at both cable ends. The grounding scheme is shown in the attached sketch ref. SubGroundSys_1-1.

2. CABLE DESCRIPTION

2.1 3x800 mm^2, 115 kV submarine cable

We are proposing 115 kV three-core XLPE insulated cables, having the construction hereunder briefly specified:

- Stranded copper conductor (longitudinally sealed)
- Semi-conducting compound screen
- Insulation with XLPE compound
- Semi-conducting compound screen
- Longitudinal water penetration barrier
- Lead alloy core sheath
- Polyethylene core sheath
- Lay-up with n° 1 optical unit and fillers
- Armor bedding
- Galvanized steel wire armoring
- Overall serving

Overall cable sizes (approx.):

-	Conductor cross section	(mm^2)	3x800
-	Diameter	(mm)	200±4
-	weight in air	(kg/m)	83±1
-	weight in sea water	(kg/m)	58±1

The detailed description of the proposed cable is specified here below.
Further constructional details and performances are stated in the Proposal Form "115 kV Three-conductor Submarine Cable", item D.

2.1.1 Conductor

The conductors offered are of compacted circular design, constructed from annealed copper wires and longitudinally water sealed in order to reduce water migration within the conductor in case of cable damage. They have a nominal cross sectional area of 800 mm^2 and the design meets the requirements laid down by IEC 60228 Class 2 standard.
A semi-conducting binder tape may be applied over the conductor.

2.1.2 Conductor screen

A semi-conducting screen layer is extruded over the conductor with an indicative thickness of 1.0-1.5 mm.

2.1.3 Insulation

The insulation consists of XLPE compound and it is applied with a nominal thickness of 15 mm.

2.1.4 Insulation screen

A semi-conducting screen layer is extruded over the insulation with an indicative thickness of 0.9 mm.
The insulation shield is securely bonded to the insulation and requires the application of heat for removal, thus assuring the consistent bond required at this important stress interface.

2.1.5 Longitudinal water barrier

Prior to the application of the metallic core sheathing, a longitudinal water barrier composed of semi-conducting water swelling tape is applied, thus limiting the water penetration along the power core in case of cable damage.

2.1.6 Lead sheathing

An extruded lead alloy sheath will be applied over the longitudinal water barrier.
Either a “E” or a “½C” alloys could be used, which are both suitable for this type of application.
The type of alloy used is dependent on the manufacturing process and experience.
The lead sheath is applied with a nominal thickness of 2.8 mm, in accordance with IEC standard.

2.1.7 Anti-corrosion sheath

An extrusion of polyethylene compound is provided over the lead sheath.
This effectively prevents any direct contact between the metallic sheath and the surrounding water environment, thus preventing the lead from corrosion as well as the dissolution of lead contaminants into water.
A semi-conductive compound is provided in order to eliminate the effect of possible over-voltages across the plastic sheaths along the cable length.
The polyethylene sheath is applied with an indicative thickness of 2 mm.

2.1.8 Assembly

The three sheathed cores and the interstitial optical unit are laid up together using a planetary type laying up machine, which avoids the imposition of torsion stresses on the sheathed cores. Suitable fillers are included in the interstices to give a substantially round shape.
The assembled cores are bound together with a synthetic tape.
The interstitial optical unit description is stated in the attached document “INTERSTITIAL OPTICAL UNIT FOR SUBMARINE COMPOSITE CABLES”.

2.1.9 Armor bedding

One layer of polypropylene strings or textile tapes is applied over the assembly as bedding for the armor wires.

2.1.10 Armor

One layer of 6 mm diameter galvanized steel wires is applied over the bedding.
The application of bitumen is provided over the armor layer as further anti-corrosion protection and to aid the adhesion of the overall serving.
Galvanizing is in accordance with the requirements of BS EN 10257-2.

2.1.11 Serving

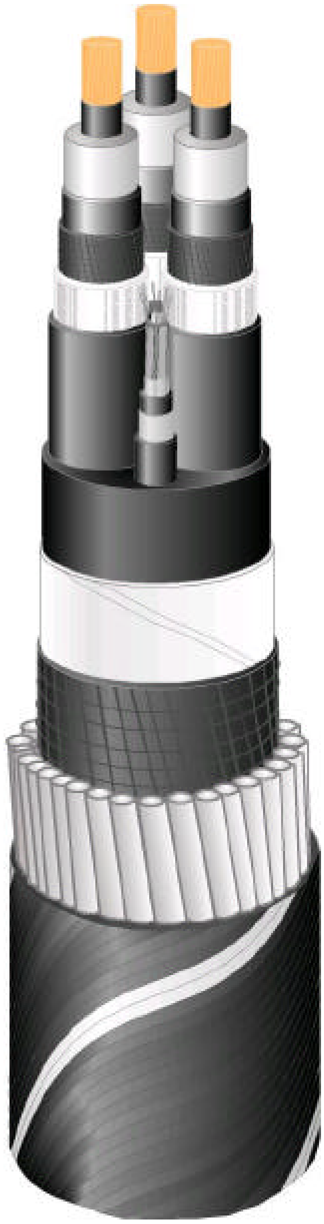
One or two layers of polypropylene strings is applied over the armor as cable serving, to provide a degree of abrasion protection and to reduce cable/skid friction during lay.
The polypropylene serving is applied with a double color pattern in order to give high visibility to the cable and enable monitoring of cable horizontal movement by ROV cameras.
The total indicative thickness is 4 mm.

2.1.12 Overall cable marking

The cables will be provided with overall colored or numbered tapes applied over the serving at regular intervals.
Our proposal is to apply a 100 m interval between tapes.

2.1.13 3x800 mm², 115 kV submarine cable - Drawing

(INDICATIVE ONLY – NOT TO SCALE)



Approximate overall sizes:

- Diameter = 200±4 mm
- Weight in air = 83±1 kg/m
- Weight in water = 58±1 kg/m

3. TESTING

The submarine cables will be subjected to factory acceptance testing and testing after installation in accordance with IEC 60840 standard recommendations.
The proposed testing program is included in the document “Tests on 115 kV Submarine Cables”.

4. ACCESSORIES

We give here below a brief description of the accessories necessary for the submarine cable circuit completion and the optional items. Where available, further accessory details are shown on attached typical drawings.

4.1 Main items

4.1.1 Armor hang-off device

The armour hang-off offered is a mechanical clamped type, which is fitted after cable is cut to length and pulled into the riser. It consists of a flange installed on top of the j-tube and a support where the armour wires are bent and held.
This type of accessory is foreseen in order to lock the cable on top of the j-tube at the offshore Electrical Service Platform (ESP).

4.1.2 Armor anchoring device

In order to prevent any possible cable movement, at the sea-land transition location, we will provide the installation of an armor anchoring device. It consists of metal clamping rings which hold the armor wires.
This accessory needs to be fixed on a concrete basement (not included in our proposal).

4.1.3 Gas immersed sealing end

Dry type gas immersed sealing ends will be provided at the ESP.

4.1.4 Sea-land power transition joint

We propose sectionalised transition joints, suitable for disconnecting the submarine metallic sheaths from the upland cable ones, thus allowing the execution of the voltage test on the upland cable plastic sheaths. This is achieved by the installation of a three-way disconnecting link box.

4.1.5 Insulated star plate

In order to allow the electrical bonding of all the cable metallic protections (metallic sheaths and armor), insulated star plates will be installed at the sea-land transition location.

4.1.6 Clamps

Suitable aluminum cable clamps will be used in order to lock the cable cores on trays or ladders at the ESP location.
The actual quantity will be defined based on the availability of the ESP layout.

4.1.7 Single-way disconnecting link box

This single-way link box is used to carry out the electrical connection between the cable metallic protections and ground, via an insulated cable.
The box is mainly composed of a polyester casing and a removable brass linking for the cable sheath connection.
One link box is provided for each cable end at the gas immersed sealing end location.

4.1.8 Three-way disconnecting link box

This three-way link box is used to carry out the electrical connection between the submarine and the land cable metallic sheaths and from these and ground, via an insulated cable.

4.1.9 Sea-land optical transition joints

We propose an optical transition joint suitable for installation both in solid ground and in splice chambers.

4.2 Optional items

4.2.1 Temperature monitoring system

As required, as option, we propose one (1) temperature monitoring systems, installed at the ESP location.
Two optical fibers are normally required for this system.
The proposed system operates with single-mode fibers.
This system is suitable for detecting the submarine portion of the circuit only.

A more detailed system description of the proposed system is given in the attached brochures.

4.2.2 Cable Load Prediction System

As a further option to the above temperature monitoring system, a Cable Load Prediction System is offered.

The functions of this system can be summarized as follows:

- To monitor the cable circuit and its environment
- To process the data monitored

The scope of the system is:

- To give actual conditions of the circuit (load, temperatures, external thermal resistivity, etc.)
- To give in every moment the optimum and safe cable loading to be achieved
- To improve design of future cable circuits

4.3 Spare parts

4.3.1 Submarine cable

We propose, as spare length, 200 m of cable as described above.
This is suitable for one repair operation to two of the four cables installed.
The 200 m cable will be supplied on a steel reel.

4.3.2 Submarine repair splices

As required, No. 4 submarine repair splices are provided.

4.3.3 Gas immersed sealing end

As required, No. 3 gas immersed sealing ends are provided.
Please refer to item 4.1.3 above for the technical description.

4.3.4 Sea-land power transition joint

As required, No. 1 insulated transition joint is provided.
Please refer to item 4.1.4 above for the technical description.

4.3.5 Armor hang-off device

As required, No. 1 armor hang-off device is provided.
Please refer to item 4.1.1 above for the technical description.

4.3.6 Armor anchoring device

As required, No. 1 armor anchoring device is provided.
Please refer to item 4.1.2 above for the technical description.

4.3.7 Single-way disconnecting link box

As required, No. 1 single-way disconnecting link box is provided.
Please refer to item 4.1.7 above for the technical description.

4.3.8 Three-way disconnecting link box

As required, No. 1 three-way disconnecting link is provided.
Please refer to item 4.1.8 above for the technical description.

4.4 Accessory drawing list

The following accessory typical drawings are attached to this proposal:

- Armor hang-off device
- Armor-anchoring device
- Gas immersed sealing end
- Sea-land power transition joint
- Insulated star plate
- Clamp
- Single-way disconnecting link box
- Three-way disconnecting link box
- Sea-land optical transition joint
- Submarine repair splice

5. OVERLOADS

The following graphs show the overload performance versus time with 75% and 100% pre-loads, relevant to the 3x800 mm^2, 115 kV submarine cables.
The calculation has been carried out in accordance with IEC 60853 standard.
The final conductor temperature is set to 105 °C.
The worst thermal condition occurs at the landing point with cables laid in the seabed at six (6) feet burial depth and individually protected by URADUCT shells.
The overload current value shown on the curves refers to the maximum admissible overload for each of the four cables.

For a better data comprehension, the results have been divided into two curves as follows:

- Figure 1 is relevant to the 0.25 h to 10 h time interval.
- Figure 2 is relevant to the 10 h to 72 h time interval.

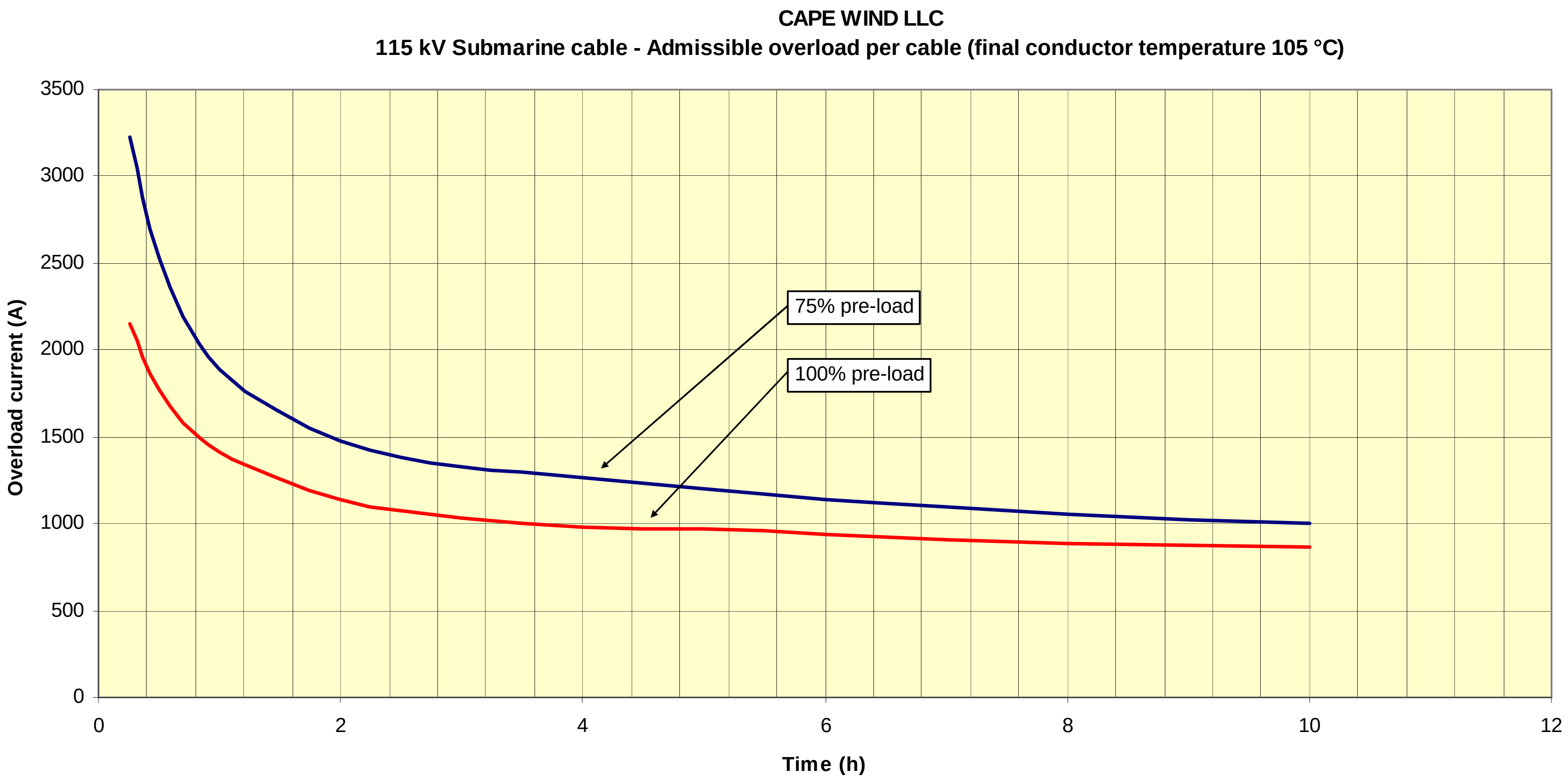


Figure 1 – 0.25 h to 10 h overload

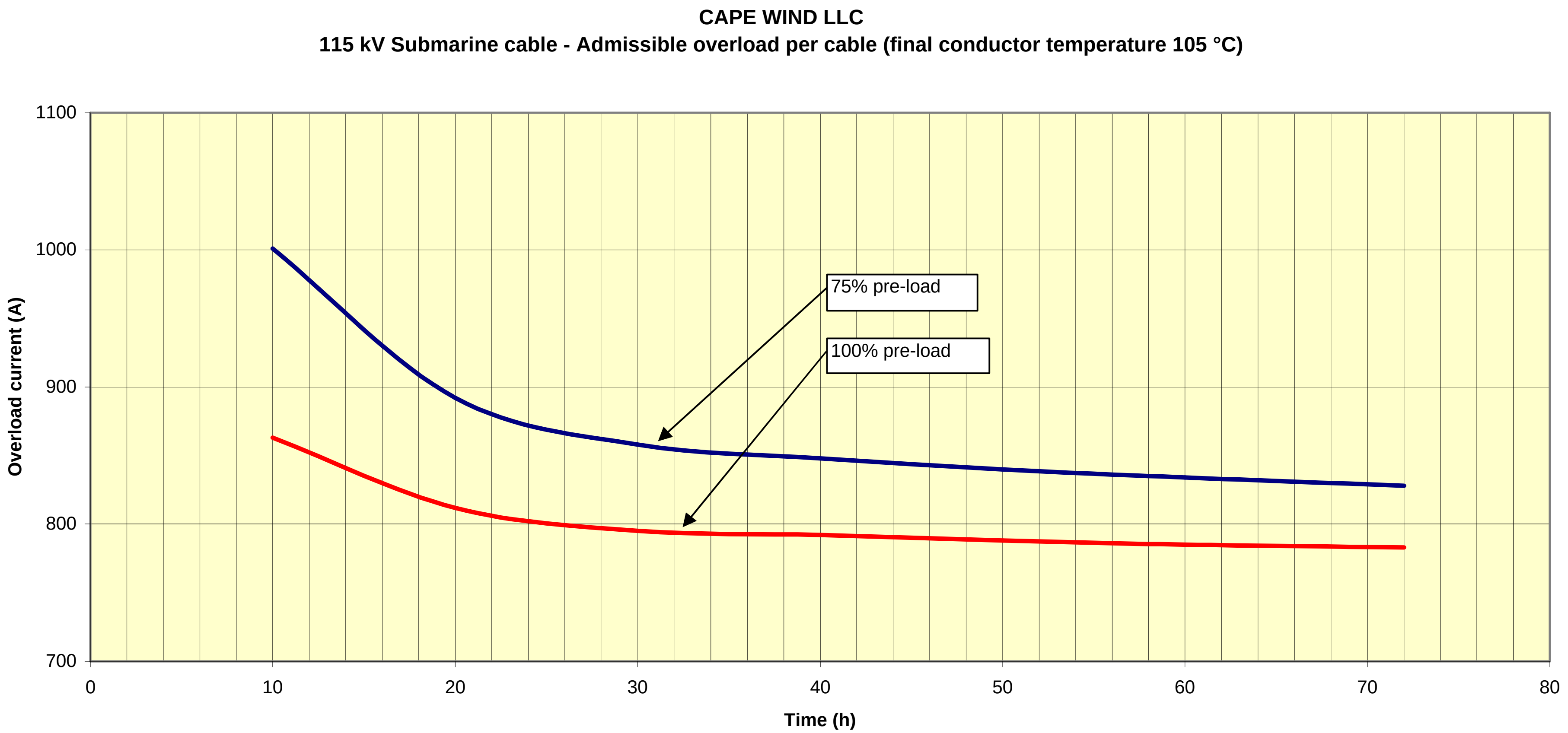
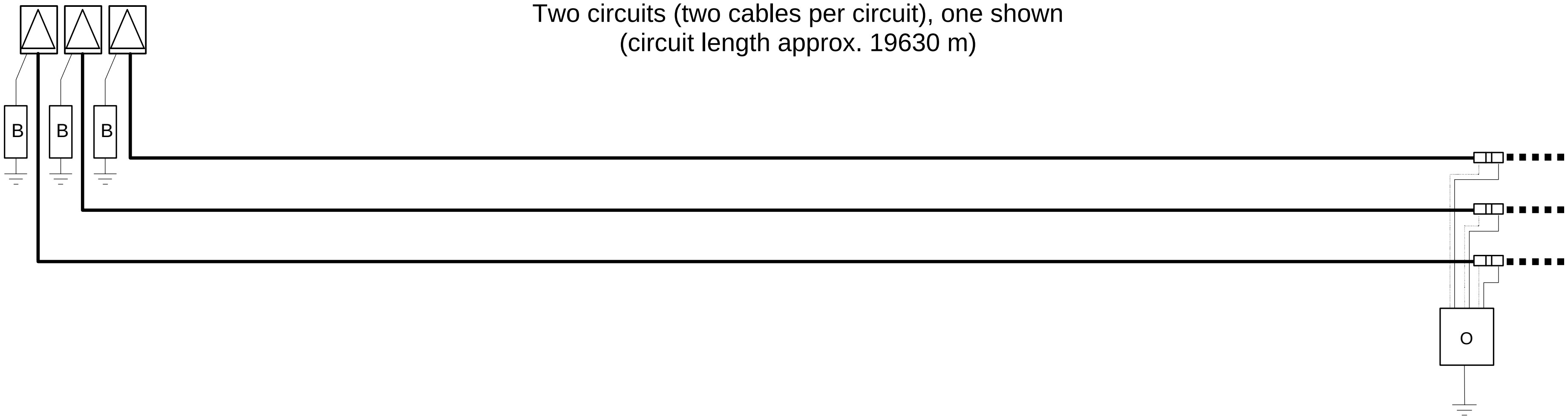


Figure 2 – 10 to 72 h overload

Cape Wind Associates LLC – 115 kV cables circuits



Drawing for guidance only

Symbols

Gas Immersed Sealing End

115 kV XLPE Submarine cable

Land cable

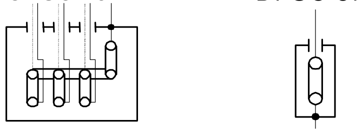
S/C bond strand

Concentric bond strand

Sectionalized Joint

O: SC 15X

B: SC 3P



Drawn by: SC Verified by:	Project: Cape Wind Associates LLC	Date: gen 2004	Dwg No.: SubGroundSys_1-1	PIRELLI

CAPE WIND ASSOCIATES LLC
115 KV SOLID DIELECTRIC UNDERGROUND CABLE
115 KV SOLID DIELECTRIC SUBMARINE CABLE
34.5 KV SOLID DIELECTRIC SUBMARINE CABLE

PROPOSAL FORM

800 sqmm Submarine Cable

D. 115 kV Three-Conductor Submarine Cable

1. Conductor

Material/stranding type	*Plain copper / Circular compact *
Stranding per IEC or ASTM?	* IEC 60228 / Class 2 *
Size of conductor/number of strands	* 800 sq mm/ *
Continuous current capacity at proposed configuration. (If less than 1262 A submit time v. current overload capability curve with Bid.)	* ≥ 631/cable A N° 2 cables in parallel per circuit
Assumed thermal resistivity of seabed	* 0.5 **(Note 1)** °K-m/W
Assumed max temperature of seabed	* (at 6 feet burial depth) 19 **(Note 2)** °C
Other factors limiting ampacity	* Uraduct installation at landing point *
	* - *
Maximum conductor temperature:	
Normal operating condition	* 90 °C
Emergency operating condition/duration	* 105 °C / 4320 min
Short circuit condition	* 250 °C
Allowable short circuit/duration	* > 40 kA rms sym/ 642 ms

2. Conductor Shielding

Type of Shielding	* Semi-conducting tape plus extruded * Semi-conducting compound
Thickness (indicative)	* (Extruded part only) 1.0-1.5 mm

3. Insulation

Type of insulation	* XLPE compound *
Thickness (nominal)	* 15 mm

4. Insulation Shielding

Type of Shielding	* Extruded semi-conducting compound *
Thickness (indicative)	* 0.9 mm

5. Metallic Shielding (other than lead alloy)

Material and Type	* - *

Thickness | * - mil

Allowable short circuit/duration | * - kA rms sym/ - ms

Type of grounding | * - *

6. Lead Alloy Sheath

Thickness (nominal) | * 2.8 mm

Allowable short circuit/duration (each lead sheath) | * 17.5 kA rms sym/ 642 ms

Type of grounding | * Solid bonding *

7. Steel Wire Armor

Number of layers | * One *

Number and diameter of wires (nominal) | * 89±2 / 6 mm

Bedding material | * Polypropylene strings or jute tapes *

Allowable short circuit/duration | * > 40 kA rms sym/ 642 ms

Type of grounding | * Solid bonding *

8. Outer serving

Material | * Polypropylene strings *

Number of layers | * One or two *

Thickness (indicative) | * 4 mm

9. Electrical Characteristics

Rated voltage (phase-to-phase) | * 115 kV rms

Maximum working voltage (ph-to-ph) | * 123 kV rms

Basic Impulse Insulation Level (BIL) | * 550 kV

DC Resistance of Conductor at 20℃ | * 0.0221 ohm/km

AC Resistance of Conductor at 60 Hz and 90℃ | * 0.034 ohm/km

Per Phase Inductance at proposed configuration | * 0.36 mH/km

Per Phase Capacitance at proposed configuration | * 0.215 uF/km

Per Phase Charging Current at proposed Configuration at 115 kV	*	5.38	A/km
Positive Sequence Resistance	*	0.060	ohm/km
Positive Sequence Reactance at Proposed configuration	*	0.136	ohm/km
Zero Sequence Resistance	*	0.143	ohm/km
Zero Sequence Reactance at proposed configuration	*	0.130	ohm/km
3-Phase Losses per circuit at 115 kV & 1262 A	**(Note 3)**		
? Dielectric Losses	*	2x1.05	kW/km
? Conductor Losses	*	2x38.7	kW/km
? Sheath Losses	*	2x16.5	kW/km
? Armor Losses	*	2x19.4	kW/km
Percent voltage drop in one circuit between ESP & landfall at 1262A, 115 kV, 0.95 pf	*	1.8	%

10. Physical Characteristics

Overall Diameter	*	200±4	mm
Minimum Bending Radius	*	3.0	m
Weight per meter of finished cable	*	83 ± 1	kg/m
Number of factory splices per circuit	*	3/core (Nominal)	*
Number of field splices per circuit other than at landfall	*	0	*
Minimum length of spare cable	*	200	m
Method of marking cable	*	Double color pattern for serving plus Numbered or colored tapes every 100 m	*
Serviceable life of cable & associated Splices and terminations	*	40	years

Note 1: Rounded up figure for 6 feet burial depth, taken from survey figures (by Geotherm Inc.).

Note 2: Average figure for 6 feet burial depth, taken from survey figures (by Geotherm Inc.).

Note 3: The figures stated are referred to one circuit losses (i.e., n° 2 three-core cables in parallel) and they are referred to the major sub sea portion with cables directly buried at 6 ft depth on top of the cables. According to IEC 60287 the dielectric losses can be neglected for this voltage level.